Chapter 2
Turbines and Pump Turbines

2-1. General

Mechanical design responsibilities in connection with turbines and pump turbines include selection of type of unit, power rating, operating characteristics and number of units, preparing contract specifications, checking contractors drawings, and coordinating related powerhouse facilities including generator, governor, air, water, and oil systems, handling provisions, and structural requirements. The guidance for turbine and pump-turbine selection is included in ETL 1110-2-317. Design of turbines is a contractor responsibility and is included under the supply contract used for turbine procurement. Coverage in this chapter is generally limited to considerations in preparation and completion of the project specifications. Turbines are a major and critical item in powerhouses and warrant maximum effort to assure practical, well-coordinated specifications with reasonable assurance of responsive bidding. In addition to the guidance referenced above, the specifications should reflect Corps experience with previous similar units and preliminary exchange of information and proposals with potential suppliers.

2-2. Francis-Type Turbines

a. Scheduling. Drawing and data submittal times, commencement and completion of work, delivery schedules, and installation work scheduling should be coordinated with general project scheduling and turbine manufacturers. Suppliers of hydraulic turbines are limited. Therefore, early contact with potential suppliers is advisable to determine their capability for bidding to the proposed dates and to assure a competitive bidding response.

b. Stainless steel runners. Stainless steel runners should be specified where possible. In many cases, they may be more economical than carbon steel runners with stainless steel overlay. However, where the benefits of stainless steel are not necessary, a carbon steel runner may be more feasible.

c. Runner overlay. The extent of chrome-nickel overlay on the runner, required for cavitation protection, is usually indeterminate at bidding time, but an estimated area is required in the specification for bid evaluation purposes. The estimate should be made on the basis of prebid information obtained from suppliers and comparisons with previous units. Extensive studies are not warranted since required areas will be determined after runner design is complete and model tested, and payment will be adjusted accordingly. The final determination of required area made by the contractor is usually accepted since it would be a factor in the cavitation guarantee.

d. Shaft diameter. The minimum shaft diameter for new construction should be computed on the basis of 38,000 kPa (5,500 psi) maximum shear stress and unity power factor. On projects where the units are being uprated the limit should be set at 41,000 kPa (6,000 psi). The maximum torsional stress should be calculated using the Mohr’s circle which combines the following stresses: stress due to the weight of all rotating parts carried by the shaft; stress created by the maximum steady-state operating hydraulic thrust; and the stress produced by the maximum torque the turbine would be allowed to produce, normally the maximum continuous duty rating (MCDR) at a power factor (PF) of 1.0.

e. Shaft length. The estimated elevation of the turbine shaft coupling should be set to realize a minimum required height of powerhouse walls, taking in to account required handling clearances of the generator rotor and shaft and the turbine rotor and shaft.

f. Shaft inspection hole. The minimum diameter of the axial hole through the turbine shaft for inspection purposes is about 100 mm (4 in.). Holes which have diameters of 150-200 mm (6-8 in.) are normally specified on the larger shafts where the reduction in strength would be insignificant. The larger holes expedite inspection and remove additional core material prone to shrinkage cavities.

g. Bearing oil heat exchanger. The pressure rating for the heat exchanger should be based on pump shutoff head if a pumped supply is required and on maximum pool plus surges where a spiral case source is to be used. The hydrostatic test should be at 150 percent of rated pressure. The maximum pressure differential across the cooler is usually specified at 68.9 kPa (10 psi) to assure satisfactory cooling. The cooling water temperature should be the maximum of the source water. However, this will usually be somewhat indeterminate, and the temperature specified should include an appropriate contingency. The cooling water source should be the same as for the generator air coolers, requiring coordination of supply heads and pressure drops. In powerhouses where available gravity head would be adequate for turbine requirements but marginal for the generator requirements a pumped supply should be provided for both. For additional comments on cooling water, refer to Chapter 10.

h. Guide bearing oil pumps. Pressurized lubrication systems are sometimes used for guide bearings, and the guide specification includes the pump requirements. However, self-lubricating bearings are practicable and are preferred for reliability and to reduce the connected DC load. An oil sump drainage pump is required when it is not practicable to drain the sump to the oil storage room by gravity. Capacity should usually be based on draining the sump in 3-4 hr. The installed pump option is preferred over a portable pump for convenience and savings in operational manhours.

i. Stay ring.

(1) Internal pressure. The stay ring should be designed for an internal pressure based on maximum pool head plus water hammer.

(2) Grout holes. Holes required for placing of grout under the stay ring are normally 50 mm (2 in.) in diameter. A diameter of 20 mm (3/4 in.) is satisfactory for vent holes.

j. Spiral case and spiral case extension. The specific requirement is dependent on the need for a field hydrostatic test, the need for a valve at the end of the penstock, and the method of connecting spiral case extension to the penstock or penstock valve.

(1) Hydrostatic test. Standard practice is to require a field hydrostatic test on all units requiring field welding. Elimination of field welding is practical only with very small cases permitting full shop assembly and shipping. The test should be specified at 150 percent of design head including water hammer. When a hydrostatic test is specified, the alternative of magnetic particle inspection for circumferential shop and field welded joints may be used. A field hydrostatic test will also require the alternative of providing a test pump and sealing off devices at the stay ring opening and inlet end of the spiral case extension. Also, when a field hydrostatic test is performed, the embedment of the case is performed while pressurized and the test pump is used to maintain design pressure in the case. The relief valve specified should be capable of being set at both the design pressure and test pressure. The pressure alarm should be actuated at a 68.9-kPa (10-psi) drop below design pressure. If circumstances are such that embedment with pressurized spiral case is impracticable, a mastic blanket covering the spiral case and extension is usually required to minimize the transmittal of operating head load to the concrete. An alternative requiring an additional 76-mm (3-in.) length of spiral case extension is necessary for cutting and finishing when removing a test head.

(2) Penstockk valve. Chapter 5 discusses factors relating to the requirements for penstock valves. Valves may be of either the butterfly or spherical type. The penstock extension-to-valve connection options are not influenced by the type of valve. Valves may be procured under the turbine contract or provided by a separate supply contract. A separate schedule should be provided when the valves are included so that award can be made by schedule or by a combination of schedules to eliminate undesirable effects on competitive bidding.

(3) Connection to spiral case extension. The choice of a flexible sleeve-type coupling or a welded joint for connecting the spiral case extension to the penstock valve or penstock depends primarily on structural considerations. These considerations involve the most practicable point at which to take the closed valve reaction and the probability of differential settlement or other structural factors affecting alignment of the penstock and spiral case extension.

(a) With penstock valve. Where a penstock valve is used, the reaction of the closed valve is generally taken by the penstock and a flexible coupling provided to connect the valve to the spiral case extension. This connection requires a straight section of penstock extension with tolerances to meet the coupling requirements and long enough to permit assembly and disassembly. Guide specification options are included for obtaining the straight section. A welded connection for valve-to-spiral case extension is satisfactory with closed valve reaction taken by the penstock and structural and foundation conditions indicating no potential misalignment problems.

(b) Without penstock valve. A welded connection should generally be used unless structural and foundation conditions indicate a possibility of misalignment problems. Where a flexible coupling is indicated, the straight penstock section will be required as with the valve-type installation.

(4) Service water. A service water connection on the spiral case extension is primarily for generator air coolers and generator and turbine bearing coolers. Unit gland water may also be from the service water connection, and in some powerhouses raw water for other powerhouse requirements is obtained from this source. The connection size specified should be based on preliminary estimates of cooling water requirements by potential

generator and turbine bidders, requirements at existing projects, crossover requirements, and the proposed powerhouse piping system. A connection is not required where a tailwater pumped supply is justified. If piping and valve location considerations warrant, the supply connection may be specified on the spiral case rather than on the spiral case extension.

(5) Drain. The spiral case-extension drain should be sized in accordance with the considerations noted in paragraph 11-2*b*(3).

k. Runner wearing rings. Wearing rings on the runner are not normally specified as operating experience has indicated little or no requirement for replacement. Stationary wearing rings above and below the runner should be specified.

l. Facing plates and wicket gate seals. Facing plates above and below the wicket gates are not required when gate seals are provided. Gate seals are usually justified. Rubber seals without facings are generally satisfactory to about 91 m (300 ft) of head. Bronze or stainless facings should be required over 91 m (300 ft) of head.

m. Air depression connection. Where an air depression system for depressing the draft water below the runner is planned, or is a future probability, a flanged connection in the head cover should be provided. Considerations pertinent to sizing the connection are discussed in paragraph 13-5.

n. Wicket gate shear pin detection. A pneumatic system for detecting a broken shear pin is not normally installed until operating experience indicates a need. The tapped hole option should be included in the specification as the cost is minimal.

o. Wicket gate servomotor pressure. Nominal system operating pressures (high end of operating range) range from 2,100-6,900 kPa (300-1,000 psi). Optimum pressure is dependent on a number of factors including: required pump displacement, pipe sizes, cost of hydraulic components, pumping horsepower, tank sizes, blade and gate servomotor sizes and location (see paragraph 2-4*a*), and service experience. Evaluation should be on the basis of overall cost of the turbine and governor system. The evaluation must be on the basis of advance information obtained from potential turbine and governor suppliers since the turbine and governor are normally obtained under separate contracts. When the advance information indicates the cost of alternate pressure systems to be approximately the same, the lower pressure system should be specified. System piping, fittings, and packing appropriate for the operating pressure should be specified. A standard pressure should be specified (refer to Guide Specification CW-11290).

p. Gate locking device. A manual device is satisfactory for the open gate position. An automatic device for the closed gate position should be provided for all units to permit automatic locking on unit shutdown.

q. Pit liner. The minimum elevation of top of pit liner should be specified to be approximately 0.6 m (2 ft) above the servomotor elevation. Minimum plate thickness should be 13 mm (1/2 in.) to permit tapped holes for the mounting of piping and equipment. One personnel entrance to the turbine pit is sufficient unless safety regulations would require an additional access for emergency escape.

r. Draft tube liner. The minimum draft tube liner thickness is usually specified at 16-19 mm (5/8-3/4 in.) depending on the draft tube size. The liner should extend down to protect concrete from water velocities over 9 m/s (30 fps) and a minimum of 0.9 m (3 ft) below the main door.

s. Rotation. The direction of rotation of the turbine runner may be specified as either clockwise or counterclockwise as far as operating characteristics of the turbine and generator are concerned. However, direction of rotation affects powerhouse layout and handling facilities to some extent and should be specified for optimum convenience and economy. Considerations in the determination of the offset of the generators with respect to the center line of a powerhouse bay are as follows: the direction of rotation, the location of the assembly area, proposed bridge crane arrangement, and proximity of the closest end wall to the generator center line. Normally cranes are designed and specified to interpose no significant restrictions on turbine design. In the case of an additional unit to be installed in an existing powerhouse, however, space and crane limitations should also be considered in specifying turbine rotation.

2-3. Francis-Type Pump Turbines

The considerations noted under paragraph 2-2 are generally applicable in completing specifications for Francis-type pump turbines.

2-4. Kaplan-Type Turbines

Items listed in paragraph 2-2 are generally applicable to Kaplan units also. Additional considerations pertinent to Kaplan units are as follows:

a. Blade servomotor location. A location requiring removal and disassembly of the runner to effect repair or replacement of the servomotor is not recommended. This would normally rule out an upper hub location as an acceptable option. Location of the blade servomotor is a factor in selecting the governor operating pressure. When the servomotor is located in the shaft, higher pressures will permit a reasonable shaft and flange diameter at the servomotor. Locating the servomotor in the runner cone below the blades is an acceptable alternative to the shaft location.

b. Head cover drain pumps. Reliability of the head cover drain pumps and power supply is of primary importance to provide maximum safeguard against flooding of the turbine guide bearing and a prolonged unit shutdown. One AC and one DC pump will usually ensure the most reliable installation. However, there is normally considerable opposition to the additional load on the station batteries. The reliability of the AC supply depends on a number of factors involving inhouse and outside sources and inhouse distribution. If a reliable backup electrical source is not practicable to obtain, backup air operated pumps or water jet educters may be justified. The mechanical design memorandum should include a discussion on the reliability of the power supply of the head cover drain pumps and backup provisions along with an evaluation of the seriousness of one or more units out of service for the necessary cleanup operation.